Multispectral Remote Sensing and COAMPS Model Analysis Methods for Marine Cloud Structure, Entrainment Processes and Refractivity Effects

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LONG-TERM GOALS

The priority goal of this research is to advance the utilization of satellite remote sensing methods to validate and implement mesoscale models for improved prediction of marine stratus and boundary layer structure.

OBJECTIVES

High accuracy in 0-30 minute prediction of cloud and inversion structure for the open ocean and coastal regions is required for Navy operations in the vicinity of stratus and fog decks. Knowledge on the probable evolution of cloud cover, cloud vertical profile and microwave refractivity at the top of the marine boundary layer (MBL) is essential for effective logistical and tactical decision-making. Our research objectives focus on the optimum utilization of parameter fields from the Navy's COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System) with geostationary satellite data for monitoring and predicting the short-term physical characteristics of boundary layer cloud and thermodynamic conditions in the vicinity of cloud top.

APPROACH

The research methodology includes studies with the COAMPS model in 1-D and 3-D versions, analysis of satellite, aircraft and model case study datasets from field measurement programs in both day and night conditions, and the development of collaboration between multiple groups from both DRI and the Naval Research Laboratory. The data collected during the COSAT (COAMPS Operational Satellite and Aircraft Test research program and previously reported (Wetzel et al., 2001), and from the DYCOMS-II (Dynamics and Chemistry of Marine Stratocumulus-II) project are being employed to evaluate marine boundary layer cloud fields as they are observed with satellite retrieval

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14. ABSTRACT
The priority goal of this research is to advance the utilization of satellite remote sensing methods to validate and implement mesoscale models for improved prediction of marine stratus and boundary layer structure.

15. SUBJECT TERMS

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techniques and model forecasts. Observational datasets such as these permit the specification of the accuracy of satellite retrievals for use in model assimilation and validation. The data are also being used to identify model-derived gridded fields which can contribute to the information content and reliability of satellite-obtained information.

As the first step in the analysis of the modeling results for the nocturnal stratus cases captured during the DYCOMS-II experiment, we will evaluate COAMPS simulations performed by NRL-Monterey. Dr. Wetzel (DRI) is developing night-time remote sensing retrieval methods for cloud physical parameters using GOES multispectral Imager and Sounder datasets. The research will include a comparison between predicted and observed radiation fluxes and microphysical parameters using satellite and aircraft data. Additional COAMPS model runs will be carried out to study the sensitivity of radiative flux and cloud predictions to model grid resolution, model physics options, and initialization fields using the more detailed observational parameters available from the field projects.

WORK COMPLETED

We have developed a large database of 15-minute GOES satellite data with accompanying aircraft and COAMPS model cases for comparative studies of daytime and nighttime stratus evolution. Satellite retrieval methods for estimation of cloud droplet size and cloud liquid water path from the GOES near-infrared and thermal infrared Imager channels have been designed. We are currently implementing and testing the revised version of the latest COAMPS model code (2.0.16) on our SGI Origin 2000 with 16 processors. This effort is led by Dr. Koracin at DRI with assistance of modeling staff in his research group. Research led by Dr. Steven Chai (DRI) focuses on development of improved numerical methods for representing the physics of the cloud top entrainment process. Numerical representation of the entrainment occurring near the cloud top uses a thermodynamic process method. Based on the analyses, various cloud top entraiment schemes, including that proposed by Telford and Chai (1984), will be tested in a one-dimensional model and then implemented and validated in COAMPS.

RESULTS

This grant began in early 2001 and the first half-year has been primarily dedicated to involvement in the DYCOMS-II field research program, design of satellite retrieval methods using GOES satellite datasets for nocturnal conditions, development of diagnositic methods for aircraft-observed entrainment processes in marine stratus, and implementation of the 1-D and 3-D models for stratus evolution.

Multispectral data are being used to characterize pixel radiative characteristics and to estimate cloud microphysical properties such as cloud droplet size, cloud liquid water path, cloud top temperature, and the spatial and temporal patterns in these parameters. Initial analysis of satellite data for the DYCOMS-II nighttime field studies in marine stratus indicate the evolution in cloud radiative signature as the cloud layer becomes deeper and more uniform during the night. A new graduate student, Narendra Adhikari, will be pursuing thesis work on radiative transfer modeling for the GOES Imager and Sounder data acquired during the DYCOMS-II case studies. With the help of a graduate student (Mr. Dong-Chul Kim, co-supported by both this project and a DEPSCoR project (Contract number N00014-01-1-0663), the θ_M-θ_A thermodynamic method developed by Telford and Chai (1993)

has been implemented for analysis of MBL entrainment conditions. The COAMPS microphysical parameterization procedure has also been incorporated to a the one-dimensional cloud physics model, and will be used with the analysis of observed entrainment conditions and cloud droplet spectra to elucidate the mechanisms of cloud physical evolution in both daytime and nighttime scenarios.

The program for plotting the θ_M-θ_A diagram developed in the present research uses specifically the IDL package, developed by Research Systems, Inc. (RSI). IDL is a powerful language for scientific applications, that provided the ability to design an interactive software widget that is objective oriented, performing thermodynamic calculations from atmospheric profile data and displaying results of the analysis in a single run. The absolute potential temperature, θ_A, is the temperature of a parcel compressed adiabatically to 1000 mb and is different from the potential temperature because in calculating θ_A, both water vapor and the cloud liquid water content are taken into consideration. The difference is large inside clouds, and the improved accuracy is needed in comparing the relative buoyancy of cloud parcels to the surrounding air or other cloud parcels, where fractions of a degree are significant. The moist potential temperature is the wet-bulb temperature, θ_M, of a parcel after it is compressed adiabatically to 1000 mb, making the air saturated by evaporation water from a reservoir at the same final temperature. The difference between this and the wet-bulb potential temperature in unsaturated air is not large (typically 0.3 K), but the importance lies in estimating the buoyancy of mixtures formed between unsaturated above cloud air and cloudy air, where good accuracy is needed. The formulas for the pressure change are derived in Telford and Chai (1984, 1993).

The θ_M-θ_A diagram has been used in analyzing the COSAT aircraft data of 9-29 August 1999 off the Oregon coast (Wetzel et al., 2001) and will be used in conjunction with our analysis of the DYCOMS-II field data for nocturnal stratus. Figure 1 shows the data of the entire COSAT flight of 9 August 1999 while Figure 2 displays the subsection of these data in the vicinity of the marine boundary layer. The dashed lines in the figure represent conditions of constant total mixing ratio and the solid numbered lines correspond to constant saturation pressure. The data points are connected with continuous lines, and identification of specific periods within an aircraft time series allows identification of MBL regions such as the sub-cloud layer, above-cloud region, and in-cloud constant-altitude sample sets. The adjacency of these points reveals the variability in the degree of parcel mixing for above-cloud air into the stratus. Preliminary analysis of the mean droplet diameter, droplet number concentration and thermodynamic data from some DYCOMS-II case studies indicates that the entity-type entrainment mixing (ETEM) process (Telford et al., 1984) was the dominating mechanism of the cloud top entrainment in data flights. This process impacts not only the evolution of cloud structure, but also the fine vertical profiles of temperature and humidity which control refractivity and microwave propagation near the MBL interface (Haack and Burk, 2001).
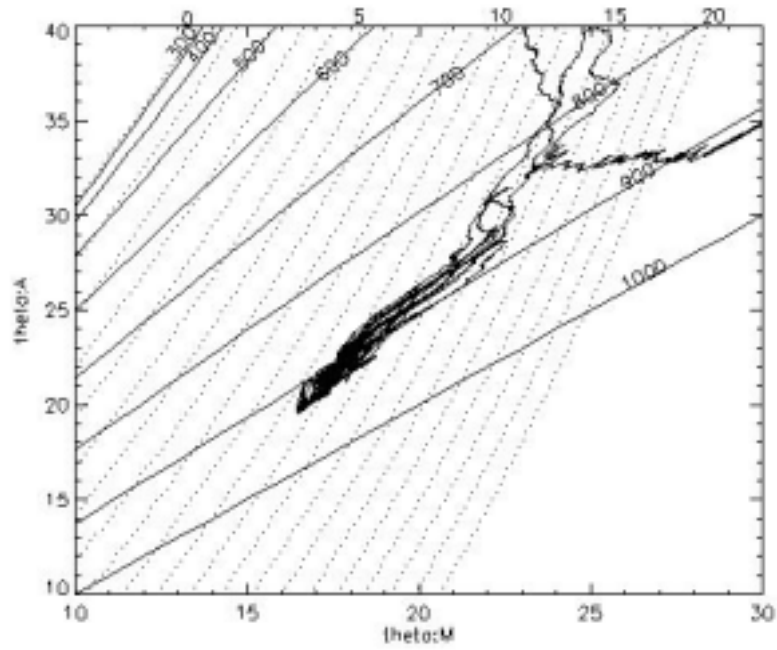
Figure 1. This θ_M-θ_A diagram shows the plotted values of the moist potential temperature and absolute potential temperature calculated from aircraft measurements during the flight of 9 September 1999 near the Oregon coast.
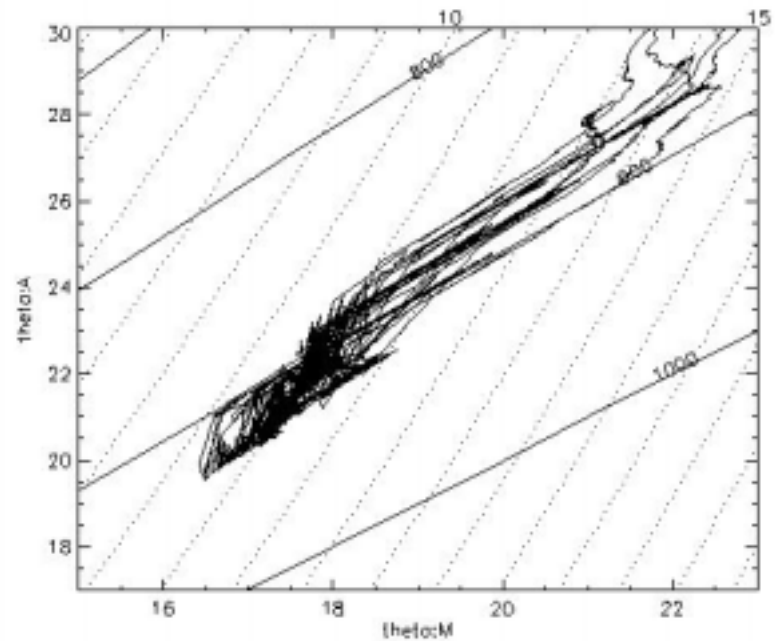

Figure 2. This diagram shows a detailed view of a section of Figure 1, for derived values of absolute potential temperature and moist potential temperature during a period of aircraft sampling near the top of the marine boundary layer.

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IMPACT/APPLICATIONS

This research will provide improved methods for obtaining and utilizing GOES satellite remote sensing products and COAMPS model results to monitor and predict the processes of entrainment to the cloud-topped marine layer. In addition, the results of these studies will be employed to advance the ability to characterize fine-scale structure in microwave refractivity conditions associated with evolution of the MBL inversion (Haack et al., 2001).

TRANSITIONS

Results of recent research have been used to improve knowledge of COAMPS accuracy and the initiate additional studies for combining GOES satellite and COAMPS model forecast datasets. The COAMPS model studies described above involve collaboration with John Cook, Tracy Haack, William Thompson and others at NRL.   The satellite remote sensing studies have led to additional cooperative research initiatives with Tom Lee and Steve Miller at NRL related to development of operational satellite products for use on Navy meteorological workstations.

RELATED PROJECTS

This research involves partnership with several other groups through the DYCOMS-II research program (www.atmos.ucla.edu/bstevens/dycoms.html ; www.joss.ucar.edu/dycoms), in addition to the NRL satellite-COAMPS model data fusion research project (DAFWa).

SUMMARY

Initial analyses of aircraft measurement data have shown that the entity-type entrainment mixing process was the dominating mechanism of the cloud top entrainment in some of the data flights analyzed from the nighttime stratus cases collected during the DYCOMS-II field program.   This procedure will be used in comparative analysis of nighttime and daytime stratus to test new model methods for representing entrainment processes at the cloud-topped marine boundary layer.   Satellite remote sensing retrieval methods for nighttime periods are being validated using research aircraft datasets and are being applied to COAMPS model verification and to identify optimal use of model- and satellite-derived parameters for MBL characterization.

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